Scaling the Merge Machinery

Elijah Newren

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Git Merge

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$(\text{Git Merge})^2$

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Outline

Affected Commands

The merge machinery (merge-recursive) powers several aspects of git:

- merge
- cherry-pick
- revert
- rebase
- am -3
- stash
- checkout -m

The journey

A few years ago...

Issues starting the journey

- cherry-pick would fail to detect renames and fail to notify about needed merge.renameLimit
- cherry-pick would ignore merge.renameLimit > 32767
- if directory renames involved, files would be left in wrong directory
- people wrote custom purpose scripts to cherry-pick things
- after fixing merge.renameLimit, cherry-picking small patches would take more than 9 minutes.

Quotes

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- “[It is] some pretty hairy code. Every time I start to look at it I get confused and can’t remember what breakthrough I thought I was close to making before.” (Jeff King)
- “I’ve written off that code as mostly unsalvageable long time ago.” (Junio Hamano)

Goals

Goals for my rewrite of the machinery are to improve each of:

- Maintainability & understandability
- API Quality (enable new features?)
- Correctness
- Performance

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Types of performance strategies

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Actual performance strategies used:

- Don’t do unnecessary work
- Don’t redo work
- Don’t redo unnecessary work
- Fudge "unnecessary"

Warning

- Glossing over lots of details
- Simplifications not fully accurate

Outline

Three-way content merge

File from branch Side1:

```
...
speak_like_a_pirate(arrrgs);
explore_sea(aye, matey);
shiver(me.timbers);
...
```

Same file from branch Side2:

```
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speak_like_a_pirate(arrrgs);
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Which results in the following merge:

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explore_sea(aye, matey);
=======
explore_sea(me.love[0]);
>>>>>>> branchB
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Shorthand:

```
          path
Base :    hash_orig
Side1:    hash_A
Side2:    hash_B
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Example:

```
          buccaneer.c
Base :    ba771ed
Side1:    57abbed
Side2:    b1a57ed
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Note: If any two of the hashes match, we can resolve without looking at the contents of the file.

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$ git checkout master
$ git merge feature
```

Get three relevant trees, then for each path:

- Get version of path in each tree
- Do three-way content merge

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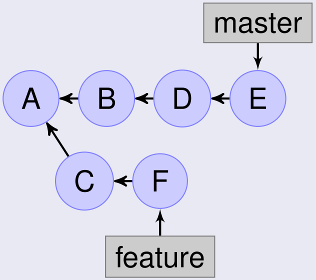
$$\begin{tikzcd}
 & & & \text{master} \arrow[d] \\
A & B \arrow[l] & D \arrow[l] & E \arrow[l] \\
 & C \arrow[ul] & F \arrow[l] & \\
 & & \text{feature} \arrow[u] &
\end{tikzcd}$$

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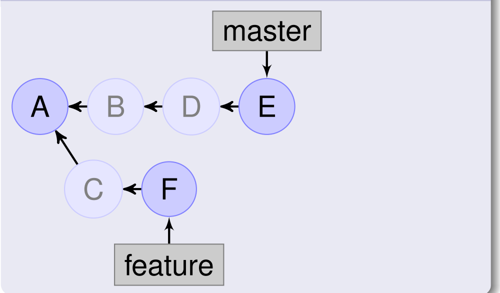

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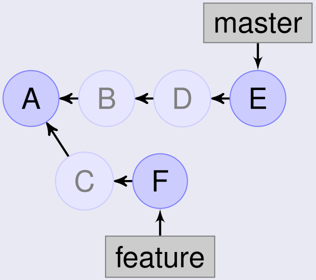

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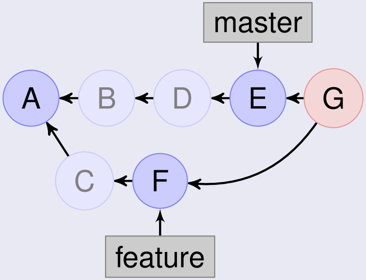

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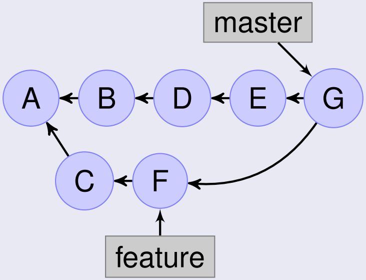
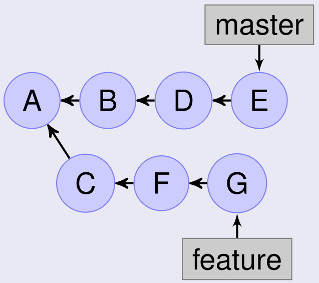


Three-way Merging

```
$ git checkout master
$ git cherry-pick C..feature
```

Starting state



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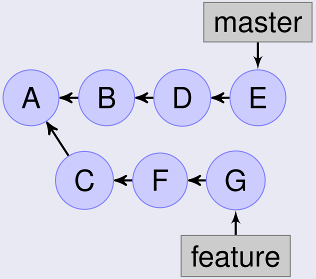
Picking F



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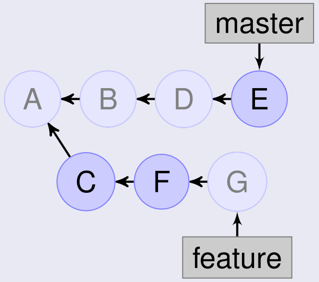

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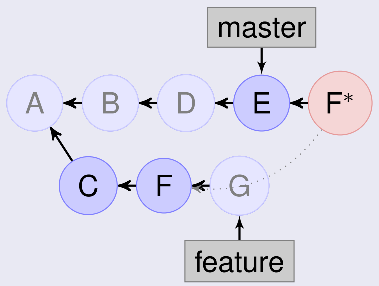

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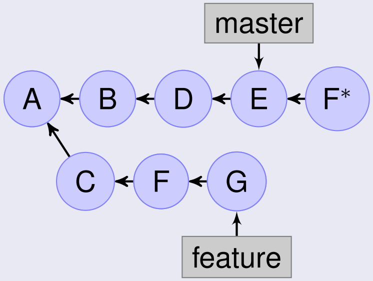

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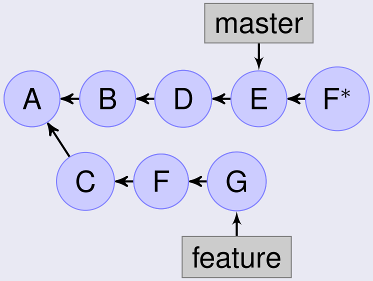

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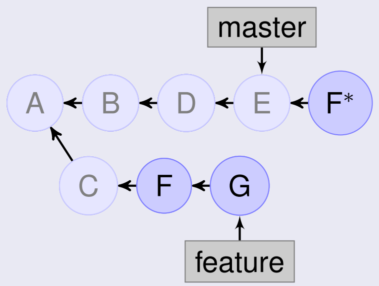

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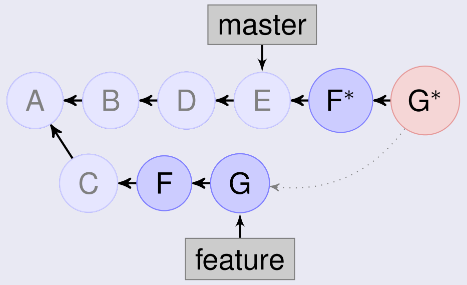

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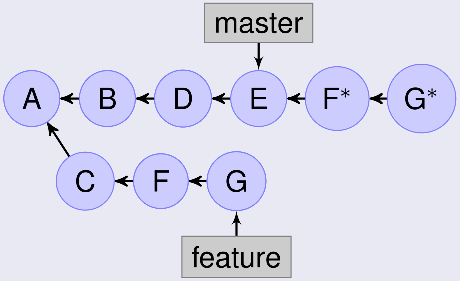

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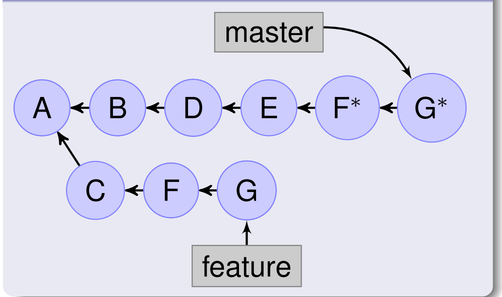
Cherry picking complete



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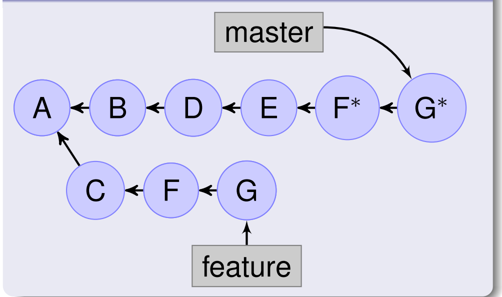

Rebasing and reverting are handled similarly to cherry-picking.

Why renames are important

If a rename is not detected:

```
        buccaneer.c   viking.c
Base:   ba771e5       0000000
Side1:  e5ca185       0000000
Side2:  0000000       defea75
```

Then:

- buccaneer.c: modify/delete conflict
- viking.c: totally new file
- no textual merging

As reported by git status:

```
Changes to be committed:
  new file:  viking.c
Unmerged paths:
  deleted by them:  buccaneer.c
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If we detect renames on each side of history:

```
        buccaneer.c ⇒ viking.c
Base:   ba771e5
Side1:  e5ca185
Side2:  defea75
Merged: acc0575
```

Then:

- buccaneer.c: removed
- viking.c: contains merged content

As reported by git status:

EITHER

```
Changes to be committed:
  renamed:  buccaneer.c -> viking.c
```

OR

```
Changes to be committed:
  deleted:  buccaneer.c
Unmerged paths:
  both modified:  viking.c
```

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  deleted:   buccaneer.c
Unmerged paths:
  both modified:   viking.c
```

Why renames are important

If a rename is not detected:

```
         buccaneer.c   viking.c
Base:    ba771e5       0000000
Side1:   e5ca185       0000000
Side2:   0000000       defea75
```

Then:

- buccaneer.c: modify/delete conflict
- viking.c: totally new file
- no textual merging

As reported by git status:

```
Changes to be committed:
  new file:   viking.c
Unmerged paths:
  deleted by them:   buccaneer.c
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If we detect renames on each side of history:

```
         buccaneer.c ⇒ viking.c
Base:    ba771e5
Side1:   e5ca185
Side2:   defea75
Merged:  acc0575
```

Then:

- buccaneer.c: removed
- viking.c: contains merged content

As reported by git status:

EITHER

```
Changes to be committed:
  renamed:   buccaneer.c -> viking.c
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How rename detection works

How does git detect renames? For each side...

Files in Base	Files in given side
README.md	README.md
archery.js	corrupt.js
baseball.js	divine.js
build.log	dull.js
football.js	grand.js
golf.js	lame.js
running.js	

For each pair of files, what percentage of lines are found in both?

	corrupt.js	divine.js	dull.js	grand.js	lame.js
archery.js					
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Matrix of similarity percentages

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Matrix of similarity percentages

How rename detection works

Crux of the problem

Rename detection is O($M * N$), where M and N are **huge.**

{M, N} ~ O(combined line count of potential rename {sources, targets})

Outline

Optimization 1: Don’t redo work

Don’t look for a better than perfect match.

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Exact renames

Detecting renames

```
void detect_renames_and_copies(...)
{
    ...
    exact_count = find_different_name_same_hash();
    /* Keep all the source files as options for copies! */
    for (dest_path in potential_rename_targets) {
        if (already_paired(dest_path)) continue;
        for (source_path in potential_rename_sources) {
            if (!DETECT_COPIES &&
                already_paired(source_path))
                continue;

            compute_similarity();
        }
    }
    ...
}
```

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Optimization 2: Don’t do unnecessary work

If you can get the same answer without an expensive computation, skip the expensive computation.

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Partial capitulation

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If a rename is not detected for the merge:

```
         buccaneer.c   viking.c
Base:    5eac0a57      00000000
Side1:   5caff01d      00000000
Side2:   00000000      c01055a1
```

Then:

- buccaneer.c: modify/delete conflict
- viking.c: totally new file
- no textual merging

As reported by git status:

```
  Changes to be committed:
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If we detect renames on each side of history:

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Merged:  0b57ac1e
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EITHER

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Same results whether or not rename is detected by merge machinery.

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Partial capitulation – Caveats?

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After unifying file collision conflict handling...

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After unifying file collision conflict handling...stdout is only difference.

Partial capitulation – micro or mega optimization?

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How much does this new strategy help?

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A Common Case

O$(M * N) \rightarrow$

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How much does this new strategy help?

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Optimization 3: Fudge “unnecessary”

Only do part of the work and accept slightly different results if there are huge cost savings.

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Only do part of the work and accept slightly different results if there are huge cost savings.

Dimensionality Reduction

Fun fact

Over 75% of renames in the linux kernel repository do not change the basename of the file, just the directory in which it is found.

Dimensionality Reduction

Detecting renames...

Files in Base	Files in given side

For each pair of files, what percentage of lines are found in both?

Dimensionality Reduction

Detecting renames...

Files in Base	Files in given side
document.html	build.log
src/blue.css	document.html
src/brown.css	source/blue.css
src/green.css	source/brown.css
src/red.css	source/green.css
	source/orange.css
	source/purple.css
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Dimensionality Reduction

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For each pair of files, what percentage of lines are found in both?

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build.log				
source/blue.css				
source/brown.css				
source/green.css				
source/orange.css				
source/purple.css				
source/red.css				

Dimensionality Reduction

Detecting renames...

Files in Base	Files in given side
document.html	build.log
src/blue.css	document.html
src/brown.css	source/blue.css
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Matrix of similarity percentages

Dimensionality Reduction

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Sparse similarity percentages

Dimensionality Reduction

Improvement

O($M * N$) $\rightarrow$ O((M-B)*(N-B))

Dimensionality Reduction

Improvement

O($M * N$) $\rightarrow$ O((M-B)*(N-B) + B)

Dimensionality Reduction

Improvement

O($M * N$) $\rightarrow$ O((M-B)*(N-B) + B)

If enough matching basenames...

O($M * N$) $\rightarrow$ O(minimum(M, N))

Optimization 4: Don’t redo unnecessary work

When repeatedly merging, re-use previous rename detection results.

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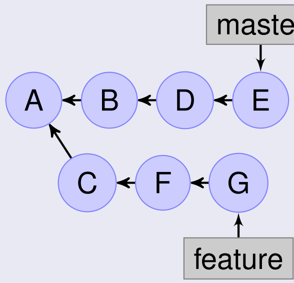
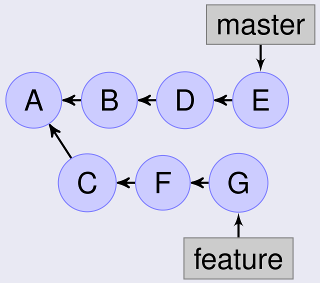
Remembering previous work

Cherry-picking C..feature



Remembering previous work

Picking F



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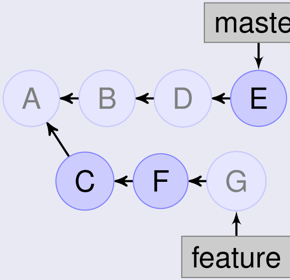

Remembering previous work

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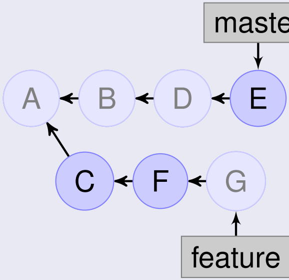

$$\left\{\begin{array}{lll} & \text{buccaneer.c} & \text{viking.c} \\ C: & \texttt{c0a575} & \texttt{000000} \\ E: & \texttt{000000} & \texttt{b1ade5} \\ F: & \texttt{befa11} & \texttt{000000} \end{array}\right\}$$

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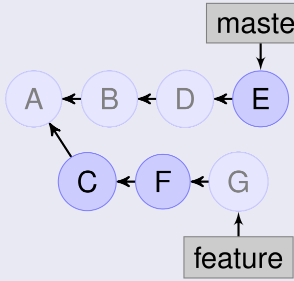

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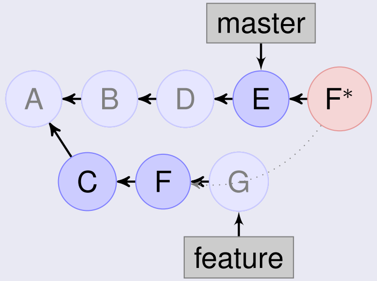

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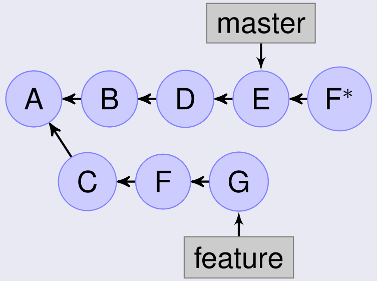
$$F^*: \quad \texttt{1007ed}$$

Remembering previous work

Picked F



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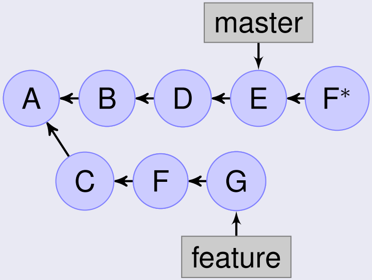
Remembering previous work

Picking G



buccaneer.c ⇒ viking.c

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Remembering previous work

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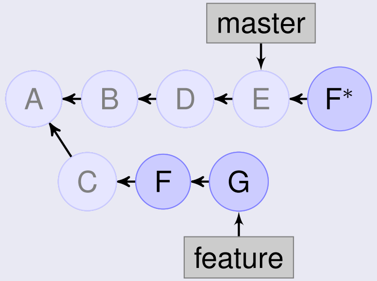

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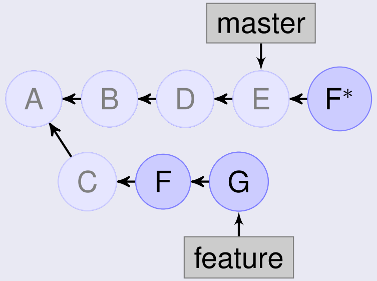

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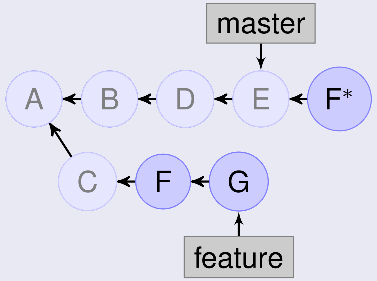

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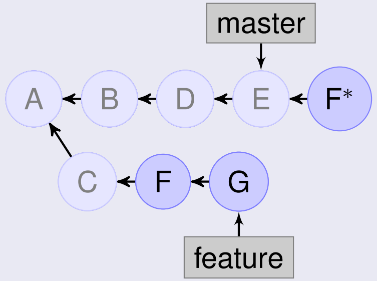

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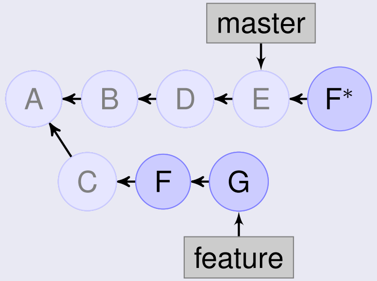

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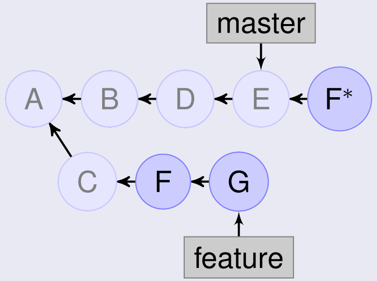

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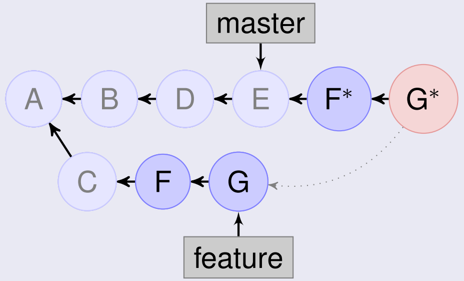

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- Avoid accidentally quadratic behavior
- Restructure to eliminate quasi-quadratic index insertion and removal
- Fewer tree traversals
- Extend “partial capitulation” ideas from *file* renames to *directory* renames
- Avoid updating the index or working tree if not needed
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Outline

Testcase

- Linux kernel
- Rebase or cherry-pick hwmon-updates (35 patches) from 5.5 $\rightarrow$ 5.4
- Very few renames involved; only takes 50% of execution time
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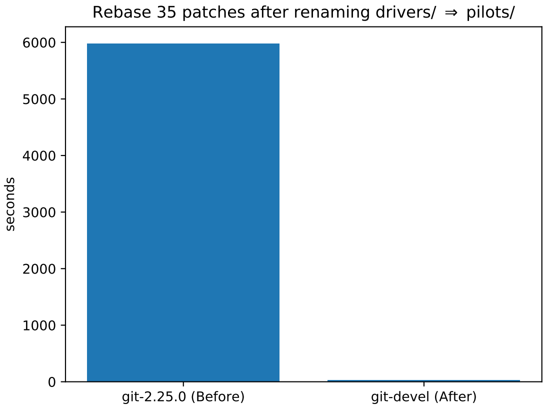
Results


Rebase 35 patches after renaming drivers/ ⇒ pilots/
seconds
6000
5000
4000
3000
2000
1000
0
git-2.25.0 (Before)
git-devel (After)

Results

Reproduce these numbers:

https://github.com/newren/git/blob/git-merge-2020-demo/README.md

The journey, redux

Issues starting the journey

- cherry-pick would fail to detect renames and fail to notify about needed merge.renameLimit
- cherry-pick would ignore merge.renameLimit > 32767
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My efforts in this area, including this performance work, represent my attempt to continue to not believe them. :-)